# Prediction of perceived quality differences between CRT and LCD displays based on motion blur

Sylvain Tourancheau, Patrick Le Callet, Dominique Barba

▶ To cite this version:

Sylvain Tourancheau, Patrick Le Callet, Dominique Barba. Prediction of perceived quality differences between CRT and LCD displays based on motion blur. Third International Workshop on Video Processing and Quality Metrics for Consumer Electronics, VPQM'07, Jan 2007, Scottsdale, AZ, United States. paper 374. hal-00256047

HAL Id: hal-00256047
https://hal.science/hal-00256047

Submitted on 14 Feb 2008

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# PREDICTION OF PERCEIVED QUALITY DIFFERENCES BETWEEN CRT AND LCD DISPLAYS BASED ON MOTION BLUR

*Sylvain Tourancheau, Patrick Le Callet and Dominique Barba*

Université de Nantes – IRCCyN laboratory – IVC team
Polytech'Nantes, rue Christian Pauc, 44306 Nantes, France
sylvain.tourancheau@univ-nantes.fr

## ABSTRACT

In this paper, a mathematical model of LCD motion blur is used to measure the magnitude of perceived blur in a sequence displayed on LCD. Subjective quality assessment tests on CRT and LCD displays are described. A difference of visual quality between the two types of displays is observed for sequences with movements. This loss of quality can be predicted from the importance of motion blur measured in the sequences. An estimation of LCD perceived quality can thus be made from CRT perceived quality. Technical solutions to LCD motion blur problem can be evaluated by this mean.

## 1. INTRODUCTION

High definition television (HDTV) is soon to be introduced in Europe. With the new resolutions of pictures, 1920×1080 in interlaced mode (1080i) and 1280×720 in progressive mode (720p), observers can reduce viewing distance down to $3H$ (where $H$ is the screen's height) to create a cinema-like experience with immediacy, presence and impact [1]. Of course, this increase in resolution leads to an increase in display size which was not possible with standard television. As a result CRT displays, which become heavy and bulky with increased screen size, are doomed to disappear. New display technologies (LCD, PDP) are improving and will soon replace old CRT technology.

It seems that LCD is more likely to succeed because of problems attached to plasma large resolution displays. However, it has been shown that subjective quality of a sequence displayed on LCD is globally lower than subjective quality of the same sequence displayed on CRT [2]. Among all the defects mentioned by observers, *motion blur* seems to be the most annoying one. This appears in sequences with rapid movements. Other shortcomings have been enumerated such as colour differences, degradations in dark areas and de-interlacing artefacts for interlaced sequences.

The objective of this study is to quantify the impact of LCD motion blur on the perceived quality on LCD with respect to the perceived quality on CRT (which is considered to be the reference here). Subjective quality assessment tests on the two types of displays are described. Results show a loss of quality between CRT and LCD. Then, a mathematical model of motion blur is used to measure the magnitude of perceived blur on each sequence. A relationship between importance of blur and quality loss can be highlighted, which enables the prediction of this quality loss.

## 2. SUBJECTIVE QUALITY ASSESSMENT

### 2.1. Material

In order to develop and evaluate new HDTV quality metrics, psychovisual tests have been designed [3]. Twelve sequences in 1080i format have been used. Each of them contain 250 frames which correspond to 10 second duration. Each reference (uncompressed) sequence has been distorted with H.264 compression standard at seven different bitrates, to cover the entire quality range. Tests have been conducted both on a CRT and on a LCD display.

In this paper, quality difference introduced by LCD motion blur is studied. For that, only the eight sequences with significant movements, and for which motion blur is the main perceived defect when displayed on LCD, have been selected. Furthermore, only quality scores of reference uncompressed sequences are considered.

Tests have been performed in a specific showroom. Lighting conditions and display parameters have been precisely measured and adjusted according to BT.500-11 and BT.710-4 ITU recommendations. The HDTV displays used were a JVC DT-V 1910CG and a Philips T370 HW01 which both can display 1080i sequences. Viewing distance was set to $3H$, where $H$ is the height of the screen.

### 2.2. Observers

Observers were mostly male students in their mid twenties. All are familiar with standard television and cinema but not with HDTV. Every candidate is first checked for color blindness with Ishihara test and for acuity with Monoyer's plates. People with at least one error in Ishihara's test or less than 9/10 in Monoyer's test are rejected. 21 people took part in these tests in the CRT session and 19 in the LCD session.

### 2.3. Protocol

The assessment method required here should allow observers to precisely construct their judgment. As very little quality differences must be detected, the method must force the quality discrimination. A well known stable method for this purpose is the SAMVIQ method [4], developed by France Telecom R&D and standardized by the European Broadcasting Union (EBU). Observers compare sequences (seven distorted sequences and one hidden reference) both between them and with the explicit reference. Notation scale is continuous, each score can take a value between 0 and 100.

SAMVIQ is a multi stimuli continuous quality scale protocol. It provides a precise and reliable [5] measure of the subjective video quality which can be compared directly to the reference. It is important to note that this reference may or may not be the original video signal. As the observers can directly compare the impaired sequences among themselves and against the reference, they can grade them accordingly. This feature permits a high degree of resolution in the grades given to the system. Moreover, observers have a random access to the sequences, which permits to choose exactly the sequence they want to assess. This allows them to precisely build their assessment opinion. This is particularly interesting in this context where very little quality differences have to be identified.

The consistency of the individual scores is evaluated after the tests have been completed by all the subjects. It is done by applying a suitable "rejection" technique. This is a process in which all scores from a particular subject are omitted from the analysis of data. Following the application of the rejection process, 15 valid subjects should be retained at minimum.

### 2.4. Results

Mean opinion scores (MOS) of observers for the eight reference sequences are shown in Table 1. ΔMOS is the difference of MOS from CRT and LCD :

$$\Delta\text{MOS} = \text{MOS CRT} - \text{MOS LCD} \quad (1)$$

Thus, subjective quality measured on LCD is lower than the one measured on CRT. It can be observed that ΔMOS is varying strongly with the sequences, as a result CRT MOS and LCD MOS are not well correlated. Correlation coefficient and root mean square error between the two MOS sets are given below :

$$CC(\text{MOS CRT}, \text{MOS LCD}) = 0.751, \quad (2)$$
$$RMSE(\text{MOS CRT}, \text{MOS LCD}) = 8.58. \quad (3)$$

To predict perceived quality on LCD from perceived quality on CRT isn't an easy task. Here the hypothesis is made that the quality difference ΔMOS depends on LCD motion blur. In the next part, LCD motion blur is described and measured on each sequences using a mathematical model.

| Séquence | MOS CRT | MOS LCD | ΔMOS |
|---|---|---|---|
| PARKRUN | 86.28 | 81.32 | 4.96 |
| SHIELDS | 84.68 | 77.95 | 6.73 |
| STOCKHOLM | 83.56 | 81.74 | 1.82 |
| CONCERT | 80.33 | 72.05 | 8.29 |
| FOOT | 83.56 | 73.05 | 10.51 |
| VOILE | 83.83 | 73.09 | 10.74 |
| SHOW | 81.15 | 69.28 | 11.87 |
| CREDITS | 82.7 | 73.76 | 8.94 |

**Table 1**. Mean opinion scores by sequences and displays.

## 3. LCD MOTION BLUR

### 3.1. Causes

Despite recent improvements to LCD technology such as response time compensation [6], LCD motion blur remains very annoying for sequences with rapid movements. In fact, even if the response time of a liquid crystal matrix was reduced to zero, motion blur would still appear. This is due to sample-and-hold behaviour of the display : the light intensity is sustained on the screen for the duration of the frame, whereas on CRT light intensity is a pulse which fades over the frame duration (cf. Figure 1). LCD displays are so called hold-type displays. The main difference happens when the eye of the observer is tracking a moving object on the screen: for a given frame, the picture is still on the screen while the eye is still moving slightly anticipating the movement of the object. Edges of this object are displaced on the retina resulting in a blur [7].

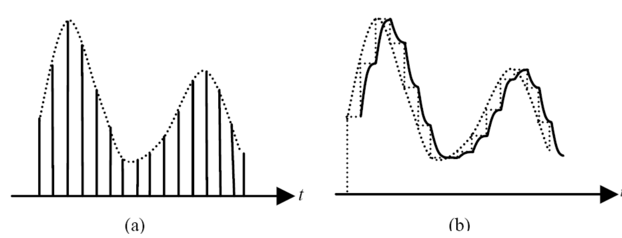


**Fig. 1**. Temporal evolution of a pixel's intensity on a CRT display (a), on an LCD display (b). (from [8])

### 3.2. Measurements

Psychophysic experiments have been conducted in order to measure blur width as a function of motion speed [3]. Since the perception of motion blur is directly related to the tracking of a moving object, measurements of blur must be done during tracking task. As a result, designed test must permit the measure of the blur while perceiving it.

Experiments consist in displaying a periodical structure of bars moving on a black background at a constant speed. The scrolling is continuous. Due to motion blur, edges of the bars don't appear sharp like shown in Figure 2-a but spread in the gap between two bars like in Figure 2-b. During the test, the observer has to modify the space between the bars until the two blurred areas begin to blend together. The space between two bars for which two blurs are just merging gives the measure of the motion blur width.

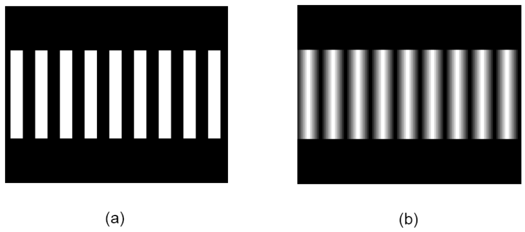


**Fig. 2**. Displayed (a) and perceived (b) images for a horizontal movement from left to right.

### 3.3. Results and model

In the explored range of speed, the width of blur is proportional to motion velocity. There is no significant difference between horizontal and vertical movements. A linear fitting (with a 0.99957 correlation coefficient) of the results leads to the following relationship between the velocity $V$ of the motion (in unit of length by frames) and the blur width $W$ (in unit of length):

$$W = 1.039V. \tag{4}$$

These results agree with the theoretical model developed by Pan *et al.* [8] which is as following:

$$W = aV. \tag{5}$$

In this model, the parameter $a$ depends on the type of temporal reconstruction function of the display. Thus, the blur width due to the displacement of an edge can be measured for different shapes of response. For example, when using a sinusoidal response, the model gives $a = 1.044$.

### 3.4. Solutions

The blur width depends on the temporal reconstruction function of the display. A material solution to reduce it is to modify the temporal aperture of the display in order to reduce the parameter $a$. Different methods have been proposed, such as backlight flashing [7, 9], frame rate doubling [7, 10], black data insertion [10] and motion-compensated inverse filtering [11].

All these methods lead to different reconstruction functions. Pan's model permits to determine parameter $a$, and then the blur width $W$, for all of these functions. Our objective here is to determine the influence of the perceived motion blur on the difference of quality between CRT and LCD. If $\Delta$MOS could be predicted from the importance of perceived motion blur, technical solutions to LCD motion blur problem could be evaluated. In the next part, a relation between LCD motion blur and $\Delta$MOS is highlighted.

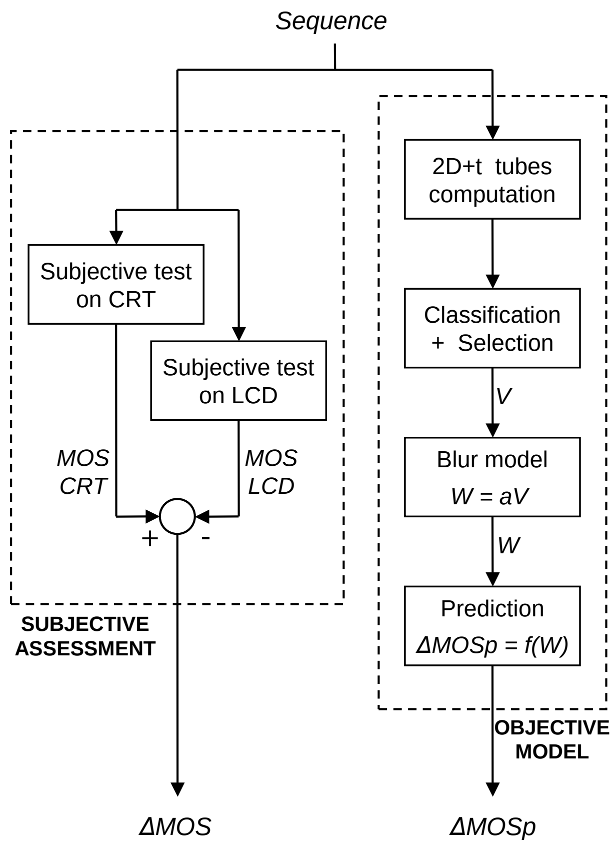


**Fig. 3**. Objective prediction of quality loss $\Delta$MOS.

## 4. QUALITY DIFFERENCE PREDICTION

Figure 3 illustrates the work done in this paper. Since subjective assessment gives a value of $\Delta$MOS for each sequence, an objective model is developed in order to predict this quality loss $\Delta \text{MOS}_p$ from the magnitude of blur in the sequence.

Prediction is made in four steps. First, a motion estimation is performed on the sequence. This leads to the construction of tubes which are the sets of blocks positions along the direction of motion. Each tube is classified according to his spatial content. Second, tubes categorized as textures and contours are selected and an average motion vector is computed from all the vectors of these selected tubes. Third, an average magnitude of motion blur is deducted from Pan's model. Fourth, $\Delta \text{MOS}_p$ is computed from a prediction model.

### 4.1. Motion estimation

As sequences are interlaced, motion estimation is made on each field. A block 16×8 of an odd (resp. even) field is simultaneously compared to blocks of the two previous and the two next odd (resp. even) fields. The position which minimizes the mean square error is chosen. Thus, a vector is obtained for each $16\times8$ block of each group of five consecutive odd (resp.even) fields.

For each group of five frames, the motion vectors of even and odd fields are then merged in order to obtain a vector for each $16\times16$ block. These blocks which are followed along five frames are so called spatio-temporal tubes. Each tubes are classified into categories: contours, textures or uniform areas.

### 4.2. Average motion blur computation

Since motion blur is only visible with a sufficient contrast [12], tubes classified contours and textures are selected. For each group of five frames, a spatial vector is computed averaging the vectors of selected tubes. These spatial vectors are then temporally averaged along the sequence. A global motion vector is obtained for each sequence.

The norm $V$ of this global vector is finally used to compute the width of perceived motion blur according to Pan's model (cf. Equation 4). This value $W$ is an indicator of the magnitude of perceived blur along the sequence.

### 4.3. Prediction model

A indicator of the quantity of perceived motion blur has been computed for each sequence. The main objective of this work is to determine the relation between the LCD motion blur and the loss of quality observed between CRT and LCD displays. A non linear function $\Delta\text{MOS}_p = f(W)$ has been constructed in order to predict the quality difference $\Delta$MOS from the average blur quantity $W$. It has been assumed that this function has the following shape. In the first part, the magnitude of motion blur is too small to influence perceived quality. In the second one, the quality loss increases with magnitude of motion blur. Finally, in the third part, the quality difference saturates despite the increase of perceived blur. This saturation may be due to contextual effects such as limited assessment scale and presence of quite distorted sequences during quality assessment.

Figure 4 presents $\Delta$MOS as a function of the quantity of motion blur for each of the eight sequences. The prediction model $\Delta\text{MOS}_p = f(W)$ is represented by the dashed line. This model can be used to predict the quality loss $\Delta$MOS between CRT and LCD from the average magnitude of blur measured on a sequence.

## 5. RESULTS

The whole objective model presented in Figure 3 enables the prediction of the difference of perceived quality between CRT and LCD for sequences with significant movements. This difference depends on the average motion blur measured on a sequence. It has been designed using sequences for which motion blur is the main perceived defect when displayed on LCD display.

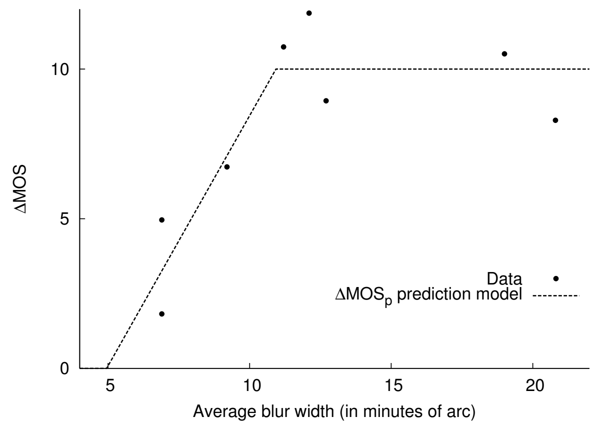


**Fig. 4.** $\Delta$MOS as a function of motion blur and prediction model.

An estimation of the subjective quality scores on LCD from the subjective quality scores on CRT can be made using the following relation:

$$\text{MOS LCD}_{est} = \text{MOS CRT} - \Delta\text{MOS}_p. \tag{6}$$

The quality of the model can be measured by the linear correlation and the root mean square error between estimated LCD scores and actual LCD scores:

$$CC(\text{MOS LCD}, \text{MOS LCD}_{est}) = 0.953, \tag{7}$$
$$RMSE(\text{MOS LCD}, \text{MOS LCD}_{est}) = 1.30. \tag{8}$$

These values can be compared with those from Equations 2 and 3. Estimated LCD quality scores are well correlated with actual scores and mean square error is quite small.

## 6. CONCLUSION

Subjective assessment quality tests have highlighted an important loss of quality between perceived quality on CRT and perceived quality on LCD for sequences with significant movements. An average magnitude of motion blur has been measured for each sequence. A model has been constructed to predict the quality difference between the two types of displays as a function of motion blur. The perceived quality on LCD has been estimated from the perceived quality of CRT.

Since quantity of perceived blur depends on LCD temporal aperture, the prediction model permits to evaluate the solutions to LCD motion blur defect. However, other aspects must be considered in order to carry out a fine prediction of perceived quality difference between CRT and LCD. Colour differences, gamma and luminosity range for example lead to differences of perception. In future, they should be incorporated into our model to finely characterize quality differences between the two types of displays.

## 7. ACKNOWLEDGMENT

This work is supported by HD4U European project. The aim of HD4U is to study best conditions to deploy HDTV in Europe. Several manufacturers from consumer devices industries (Philips, Thomson, etc.) and broadcasters (TF1, Euro1080) are involved. Authors would like to thank SVT for the open HDTV sequences, and Thomson and Philips for the HDTV screens. They would also like to thank Mathieu Carnec for the development of the motion estimation algorithm and Arnaud Tirel for his assistance in performing the experiments described in the paper.

## 8. REFERENCES

[1] Takashi Fujio, "Future broadcasting and high definition television," NHK technical monograph, NHK, June 1982.

[2] ITU, "Report on results of comparative subjective picture quality assessment test between CRT and LCD," Questions ITU-R 95/6, 102/6, International Telecommunication Union - Radiocommunication Study Groups, August 2005.

[3] Stéphane Péchard, Sylvain Tourancheau, Patrick Le Callet, Mathieu Carnec, and Dominique Barba, "Towards video quality metrics for HDTV," in *Proceedings of the Second International Workshop on Video Processing and Quality Metrics, VPQM'06*, Scottsdale, January 2006.

[4] EBU, "SAMVIQ – Subjective assessment methodology for video quality," Tech. Rep., European Broadcasting Union, 2003.

[5] Jean-Louis Blin, "New quality evaluation method suited to multimedia context: Samviq," in *Proceedings of the Second International Workshop on Video Processing and Quality Metrics, VPQM'06*, Scottsdale, January 2006.

[6] Richard I. McCartney, "A liquid crystal display response time compensation feature integrated into an LCD panel timing controller," *SID Symposium Digest of Technical Papers*, vol. 34, no. 1, pp. 1350–1353, May 2003.

[7] Taiichiro Kurita, "Moving picture quality improvement for hold-type AM-LCDs," *SID Symposium Digest of Technical Papers*, vol. 32, no. 1, pp. 986–989, June 2001.

[8] Hao Pan, Xiao-Fan Feng, and Scott Daly, "LCD motion blur modeling and analysis," in *IEEE International Conference on Image Processing, 2005. ICIP 2005.*, September 2005, vol. 2, pp. 21–24.

[9] Xiao-Fan Feng, "LCD motion-blur analysis, perception, and reduction using synchronized backlight flashing," in *Proceedings of the SPIE Conf. Human Vision and Electronic Imaging XI*. Electronic Imaging 2006, Janvier 2006, vol. 6057.

[10] Sunkwang Hong, Brian Berkeley, and Sang Soo Kim, "Motion image enhancement of LCDs," in *IEEE International Conference on Image Processing, 2005. ICIP 2005.*, September 2005, vol. 2, pp. 17–20.

[11] Michiel A. Klompenhouwer and Leo Jan Velthoven, "Motion blur reduction for liquid crystal displays: motion-compensated inverse filtering," in *Proceedings of the SPIE Conf. Visual Communications and Image Processing 2004*. Electronic Imaging 2006, January 2004, vol. 5308, pp. 690–699.

[12] Justin Laird, Mitchell Rosen, Jeff Pelz, Ethan Montag, and Scott Daly, "Spatio-velocity CSF as a function of retinal velocity using unstabilized stimuli," in *Proceedings of the SPIE Conf. Human Vision and Electronic Imaging XI*. Electronic Imaging 2006, Janvier 2006, vol. 6057.